

SM Higgs Searches: ATLAS

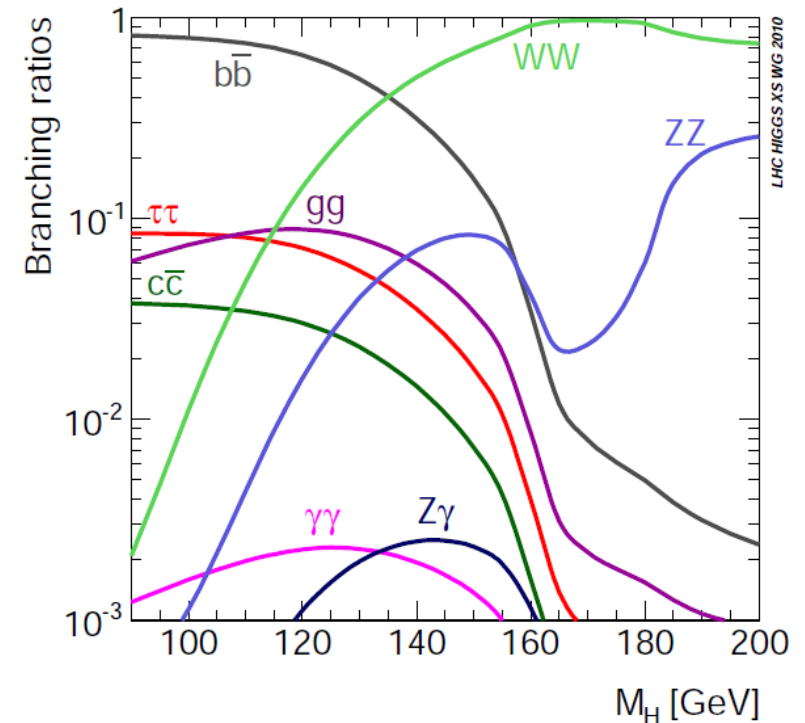
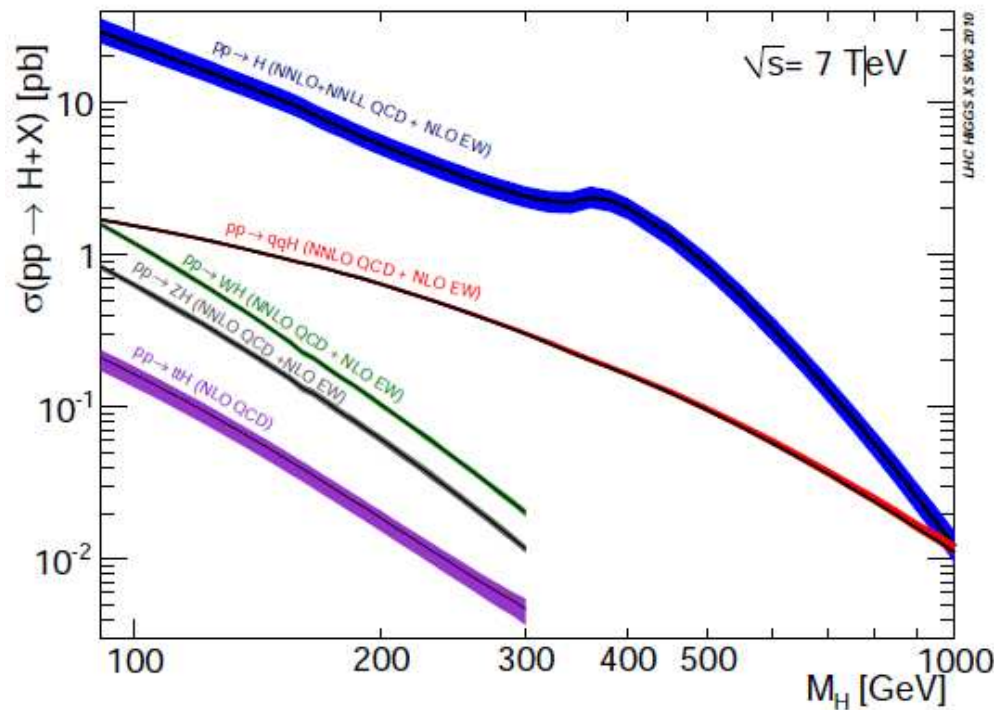
Jonas Strandberg
on behalf of the
ATLAS Collaboration

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3. $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
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1. Introduction

- This talk will discuss the ATLAS results for SM Higgs boson searches that were presented at the winter conferences this year.
 - Covers the most sensitive channels but there are many more efforts going on in the collaboration.
- The dataset used is the pp collisions (at 7 TeV) from 2010.
 - The integrated luminosity for the different channels varies between $\mathcal{L}_{\text{int}} = 35\text{-}43 \text{ pb}^{-1}$.
- The question of which statistics method to use for the exclusion limit has been hotly debated recently.
 - ATLAS default results obtained with the Power Constraint Limit (PCL) CL_{s+b} method. Typically give 20% better limits than CL_s .
 - In this talk most of the results will be given with both the PCL CL_{s+b} and CL_s methods (for comparison).

Higgs Boson Production and Decay



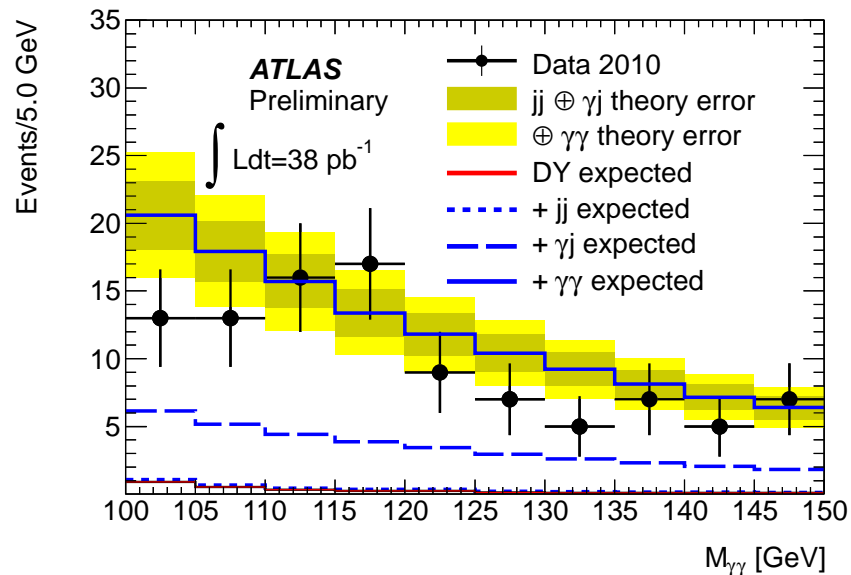
- Of the possible combinations of production and decay modes, six different channels were used for the winter confs.
 - All calculations of cross sections and branching ratios are taken from the LHC Cross Section Working Group.

2. The $H \rightarrow \gamma\gamma$ Search

- Events are selected requiring two photons with $p_T > 40$ GeV and $p_T > 25$ GeV and that the invariant mass is $100 < m_{\gamma\gamma} < 150$ GeV.
 - There are 99 events in data passing these selections.
- The main backgrounds are from $\gamma\gamma, \gamma j, jj$ and DY production.
 - Bkg composition derived from data and verified with MC.
- The di-photon mass full-width-at-half-maximum is around 4.4 GeV for a Higgs boson mass of $m_H = 120$ GeV.
- The expected number of $H \rightarrow \gamma\gamma$ signal events passing all analysis cuts for a few selected Higgs boson masses are:

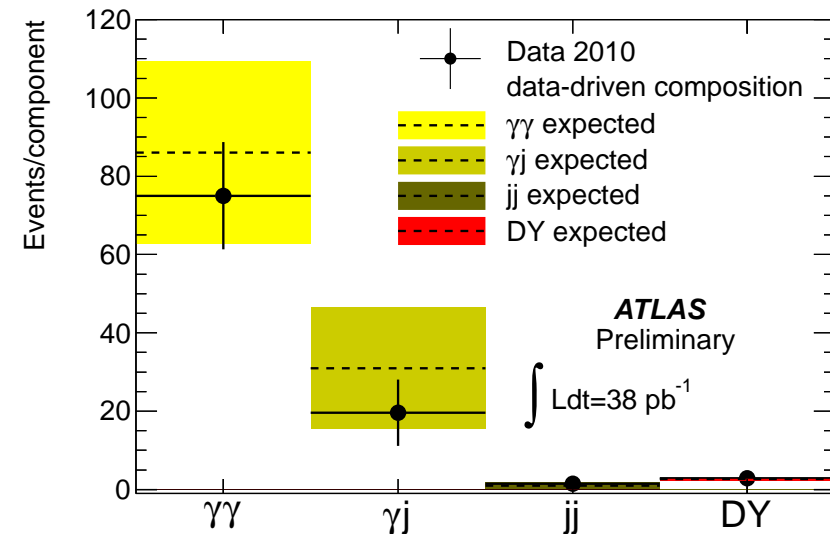
Higgs boson mass (GeV)	110	115	120	130	140
Number of signal events	$0.43^{+0.11}_{-0.09}$	$0.45^{+0.11}_{-0.10}$	$0.45^{+0.11}_{-0.10}$	$0.41^{+0.10}_{-0.08}$	0.31 ± 0.08

Background Composition in the $H \rightarrow \gamma\gamma$ Search



Di-photon invariant mass

- The 99 candidate events and the expected composition of the background.

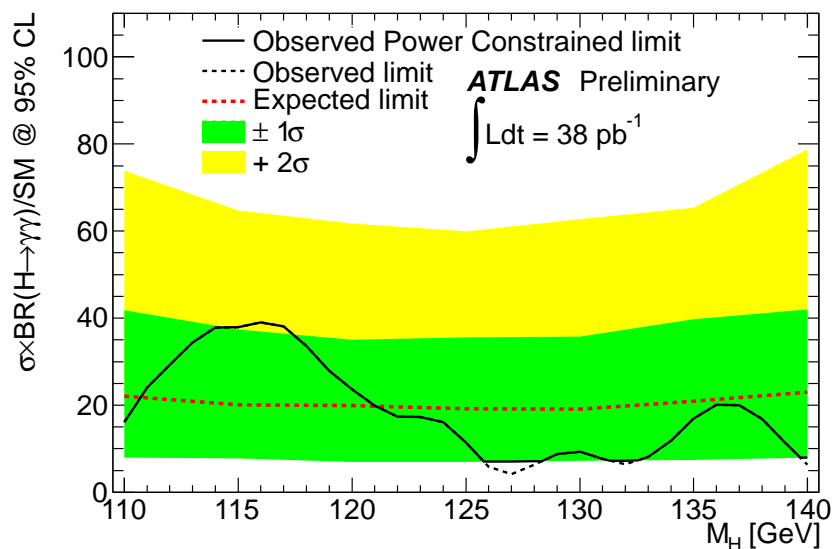


Background components

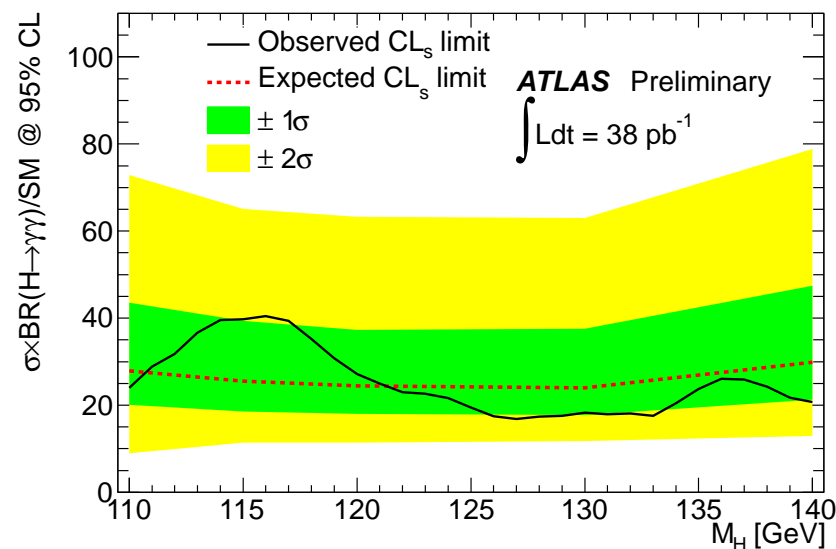
- Comparison of the background composition derived from the data and from MC.

Exclusion Limit for the $H \rightarrow \gamma\gamma$ Search

- The exclusion limit calculated with Power Constraint Limit (PCL) CL_{s+b} and the CL_s methods (for comparison).
 - Exclusion limits comparable to the Tevatron limits for $H \rightarrow \gamma\gamma$.



PCL CL_{s+b} limit

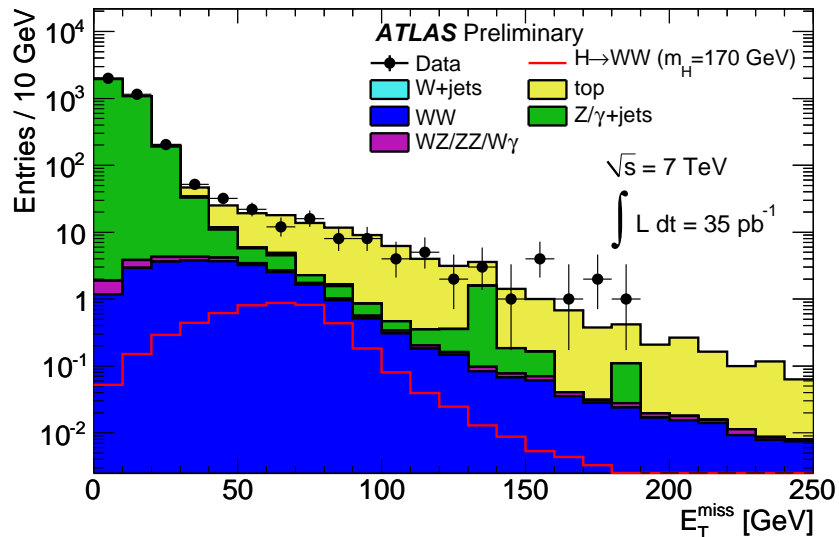


CL_s limit

3. The $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ Search

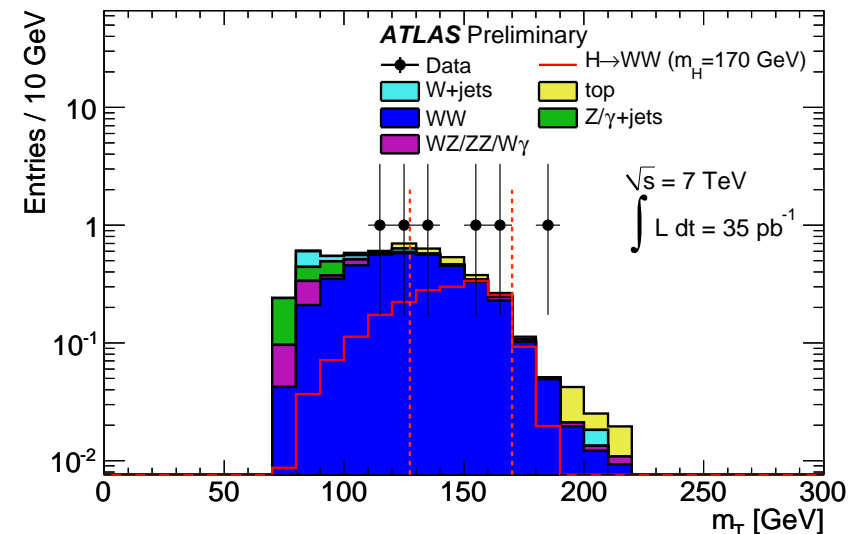
- The $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ channel benefits from relatively large branching ratio and very clean dilepton signal.
- Important event selections are for example:
 - Requiring two leptons with $p_T > 20$ GeV and $p_T > 15$ GeV.
 - Requiring missing transverse energy $E_T^{\text{miss}} > 30$ GeV.
 - Requirements on $m_{\ell\ell}$, $\Delta\phi(\ell, \ell)$ and the transverse mass
$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{\text{miss}})^2 - (\mathbf{P}_T^{\ell\ell} + \mathbf{P}_T^{\text{miss}})^2}.$$
- Events are treated separately depending on the lepton flavors (ee , $e\mu$ and $\mu\mu$) and the number of jets (0, 1 and 2 jets).
 - In total nine different channels considered.
- Analysis done for Higgs masses between $120 < m_H < 200$ GeV.

The 0-jets Channel



E_T^{miss} after selecting two leptons

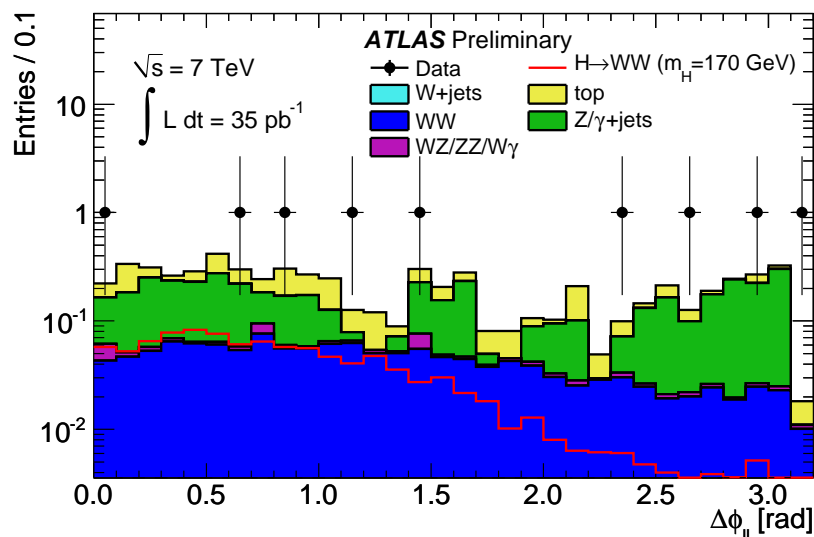
- Before the E_T^{miss} selection, dominated by Z/γ^* events.
 - Suppressed by the E_T^{miss} and $m_{\ell\ell}$ requirements.



m_T for the final candidates

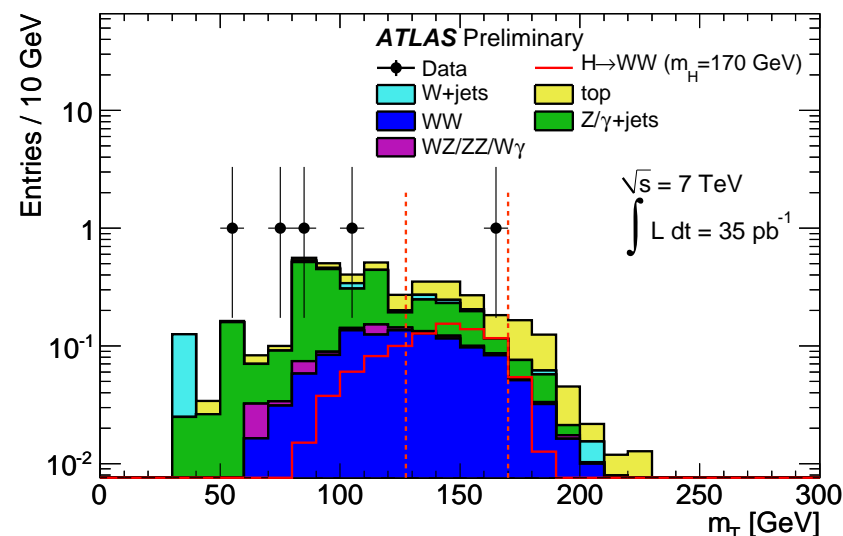
- Plot shows the m_T distribution before selecting on it.
 - Three events within the dashed lines survive cuts.

The 1-jet Channel



$\Delta\phi(\ell, \ell)$ before selection

- Opening angle between the leptons expected to be small.
 - Require $\Delta\phi < 1.3$ (< 1.8) for $m_H < 170$ ($m_H > 170$) GeV.

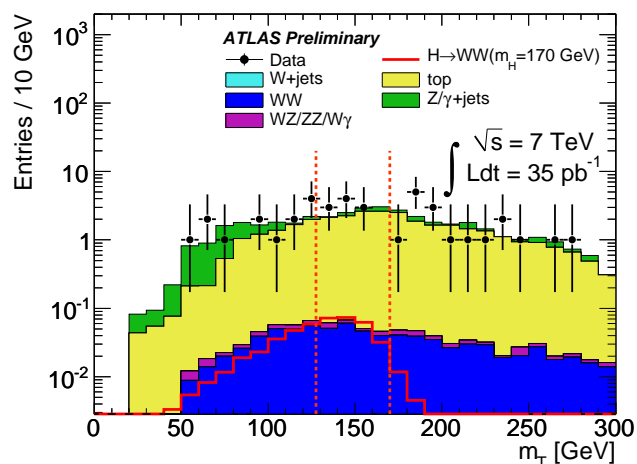


m_T for the final candidates

- Plot shows the m_T distribution before selecting on it.
 - One event within the dashed lines survives cuts.

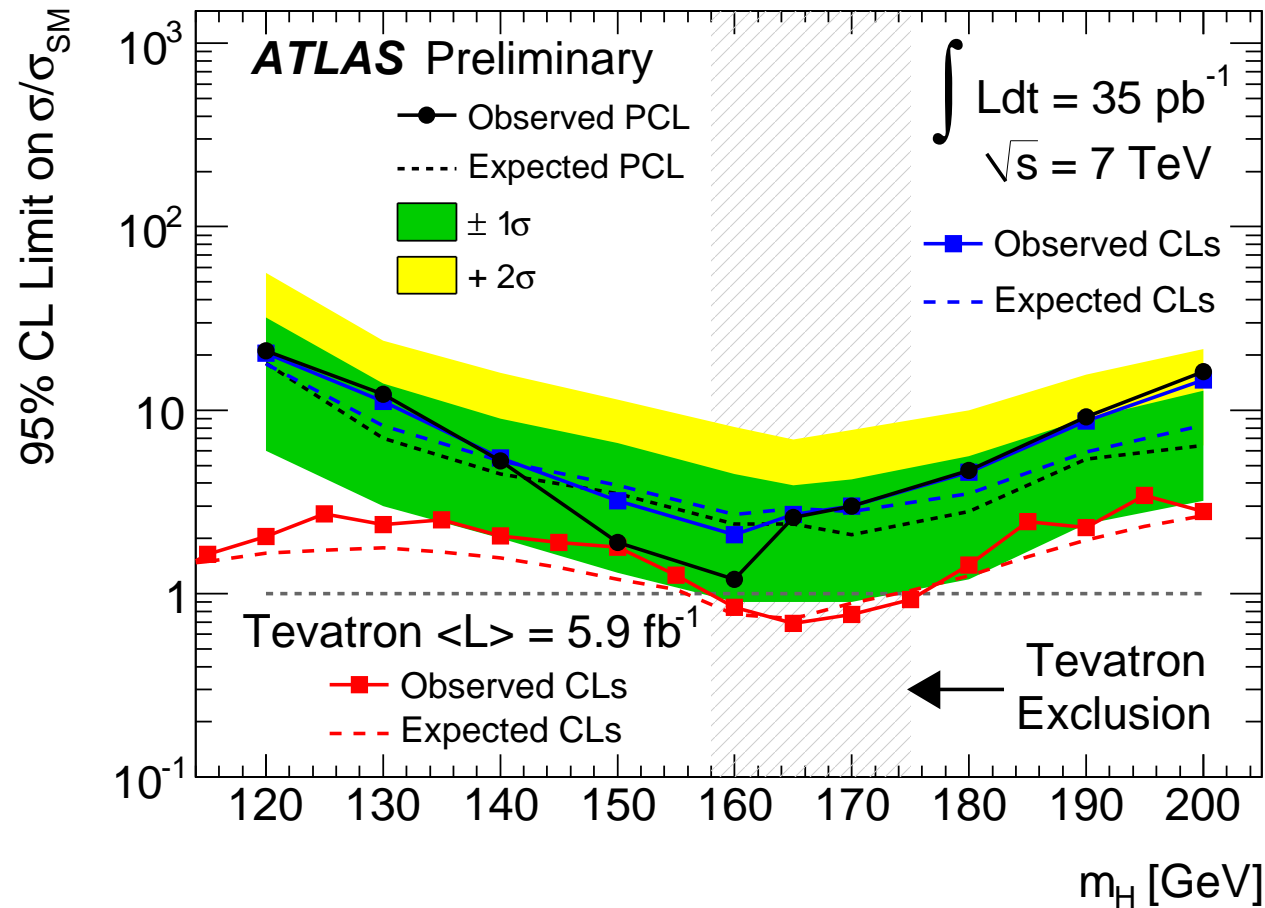
The 2-jets Channel

- The 2-jets channel mainly targeted for the signal events produced through the vector boson fusion production mode.
 - Tight selections on the two tag jets increase the S/B .
 - Low expected yields for the current integrated luminosity, analysis more suitable for larger data samples.
- No events pass all the event selections, 0.02 signal events and 0.06 background events expected for $m_H = 170$ GeV.



- Forward jet distributions studied with the first data, looks very well modelled by Monte Carlo.
- Plot shows m_T distribution after only the lepton selections and some tag jet selections have been applied.

Exclusion Limit for $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$

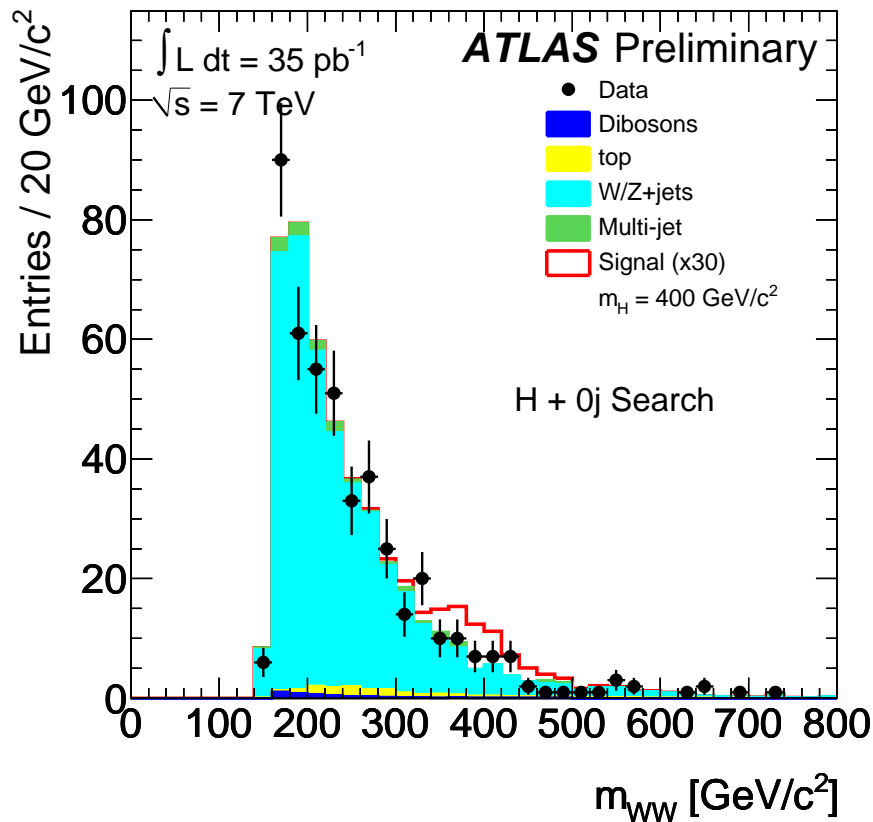


- Exclusion limit calculated with both PCL CL_{s+b} and CL_s methods.

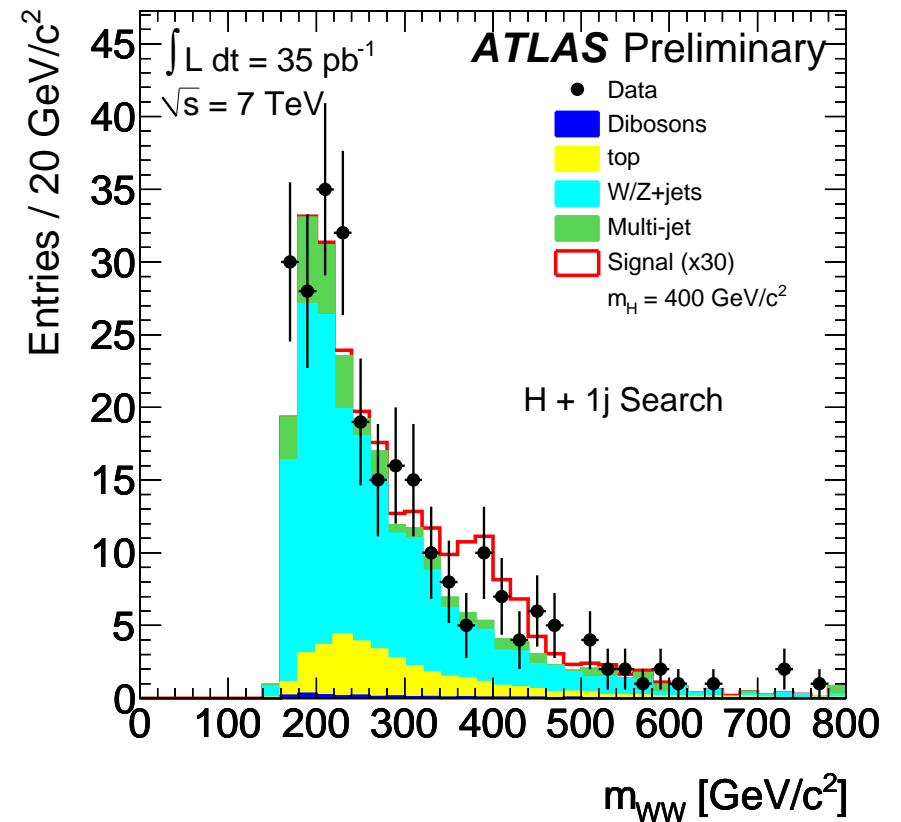
4. The $H \rightarrow WW \rightarrow \ell\nu qq$ Search

- The $H \rightarrow WW \rightarrow \ell\nu qq$ channel offers good sensitivity for high m_H .
 - Analysis performed for Higgs masses $220 < m_H < 600$ GeV.
- The main event selections include:
 - Requiring one lepton with $p_T > 30$ GeV.
 - Requiring that the $E_T^{\text{miss}} > 30$ GeV.
 - Requiring two or three jets in the event.
- The discriminant variable is the WW invariant mass. Look for a peak on top of the continuous background.
- The main backgrounds are from W +jets and $t\bar{t}$ production.
 - For a Higgs boson mass of $m_H = 400$ GeV, about 2 signal events expected for an estimated background of 670 events.

The WW Invariant Mass Distributions

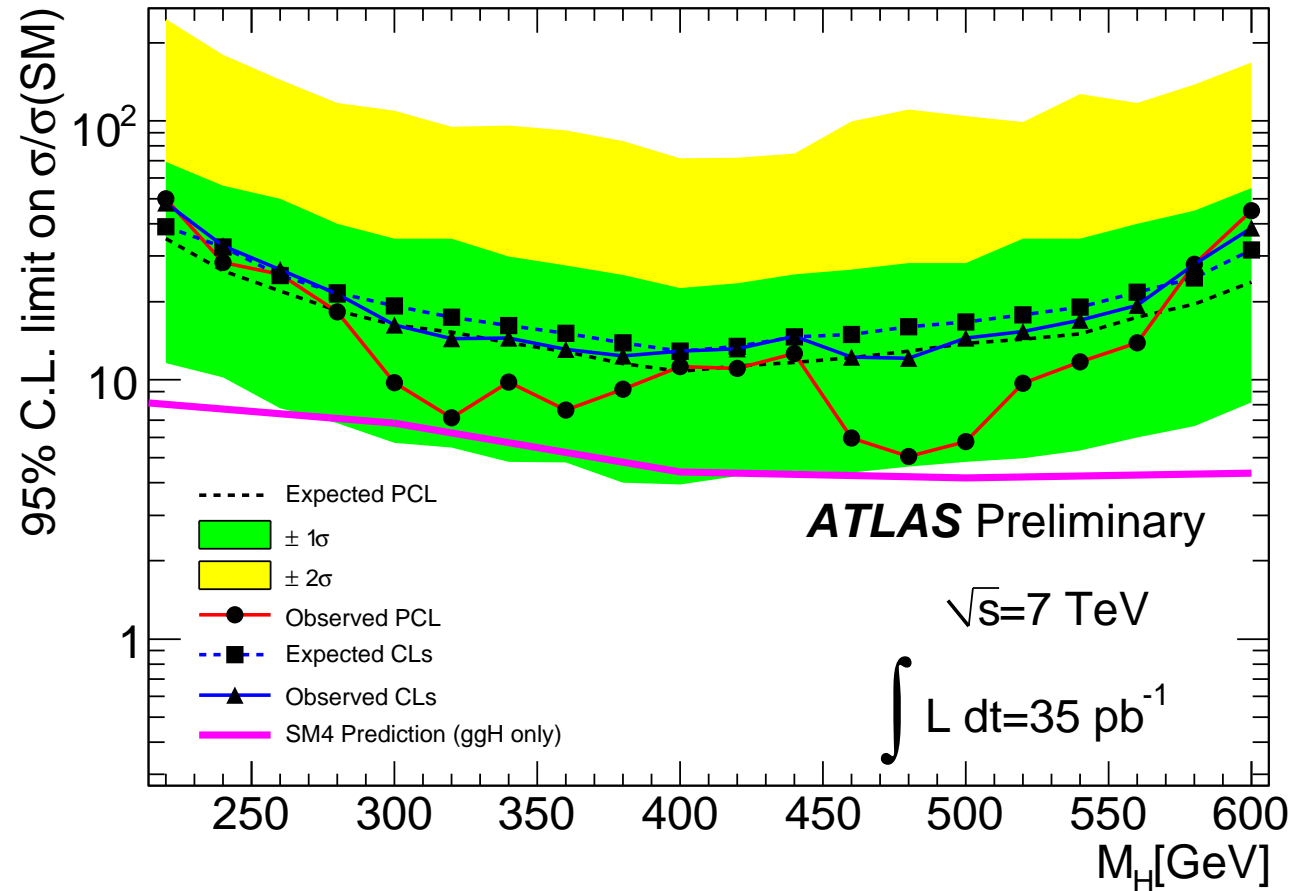


H + 0 jets channel



H + 1 jet channel

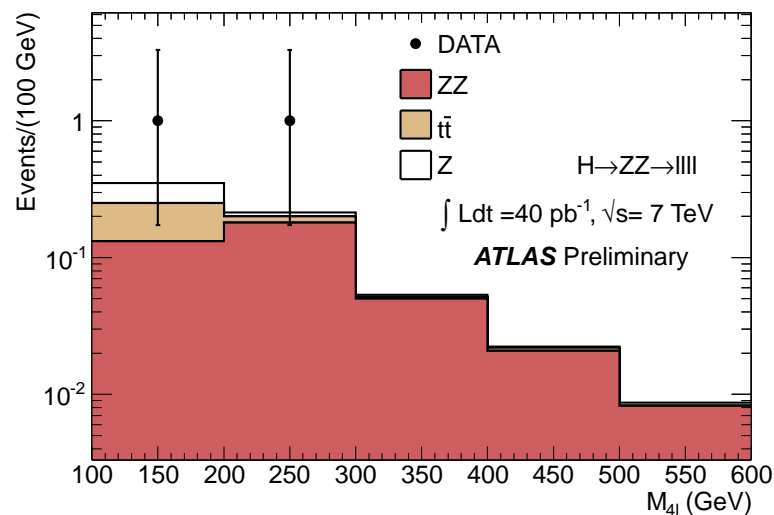
Exclusion Limit for $H \rightarrow WW \rightarrow \ell\nu qq$



- Exclusion limit calculated with both PCL CL_{s+b} and CL_s methods.

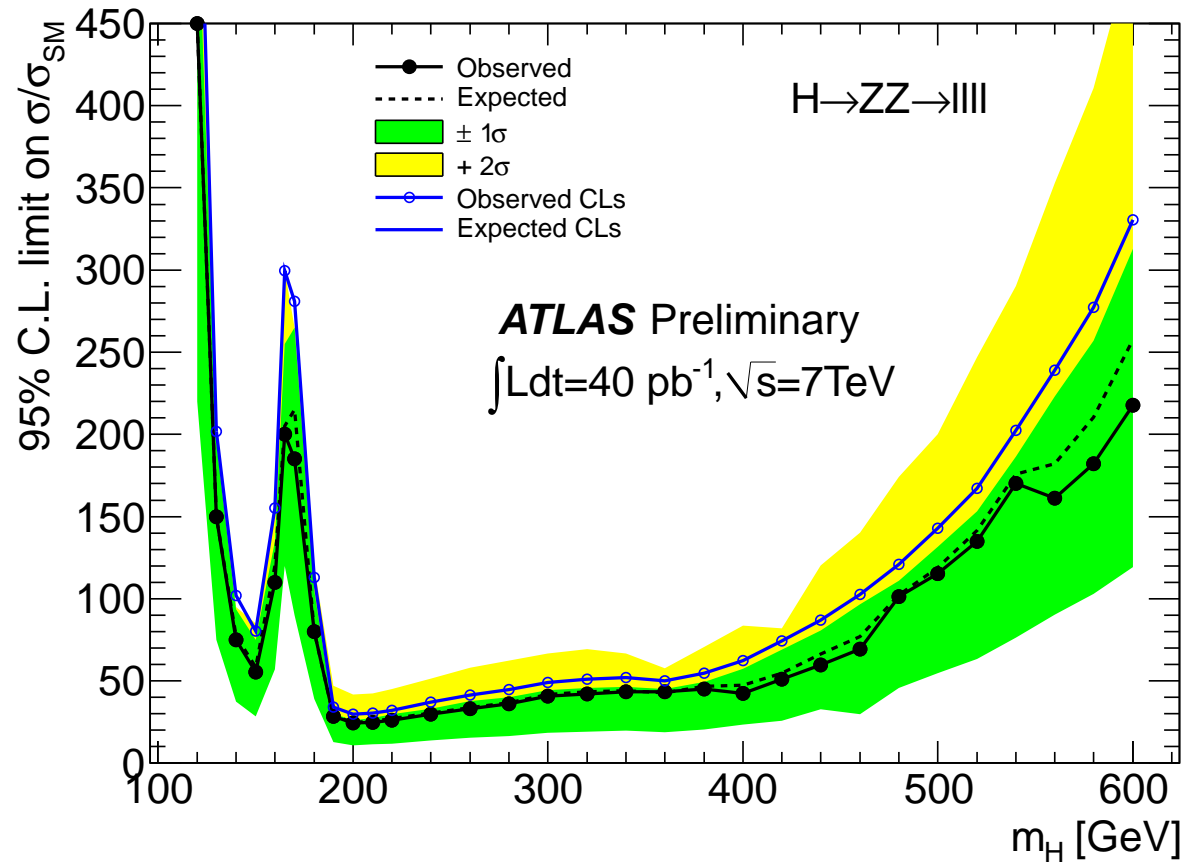
5. The $H \rightarrow ZZ^{(*)} \rightarrow llll$ Search

- The $H \rightarrow ZZ^{(*)} \rightarrow llll$ is the experimentally cleanest signature.
 - Very narrow signal peak in the m_{llll} distribution can be reconstructed on top of the continuous background.
 - Analysis done for Higgs boson masses $130 < m_H < 600$ GeV,
- Event selection requires two pairs of opposite-charge same-flavor leptons. Two leptons required to have $p_T > 20$ GeV.



- Expected number of selected events low at current luminosity.
 - No events observed in data.
- Plot shows the m_{llll} distribution before the isolation selections are applied to the leptons.

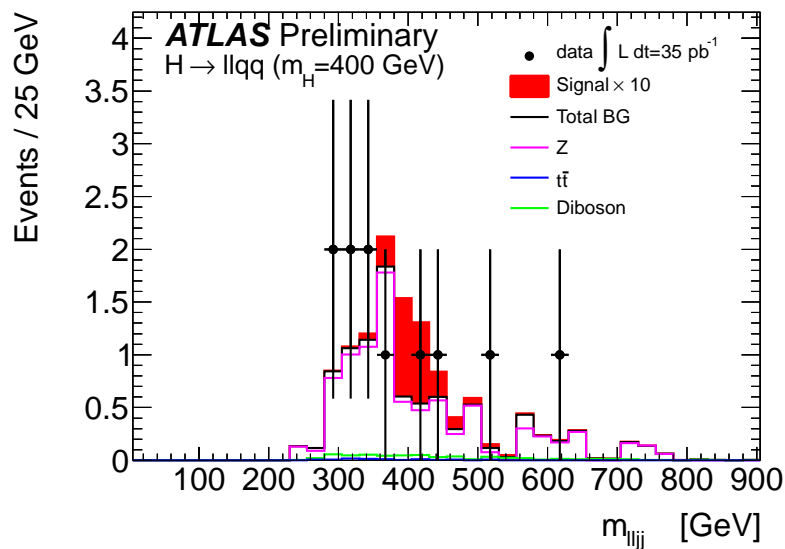
Exclusion Limit for the $H \rightarrow ZZ^{(*)} \rightarrow llll$ Search



- Exclusion limit calculated with both PCL CL_{s+b} and CL_s methods.
 - Essentially bkg free search, expect limit to improve as $1/\mathcal{L}_{int}$.

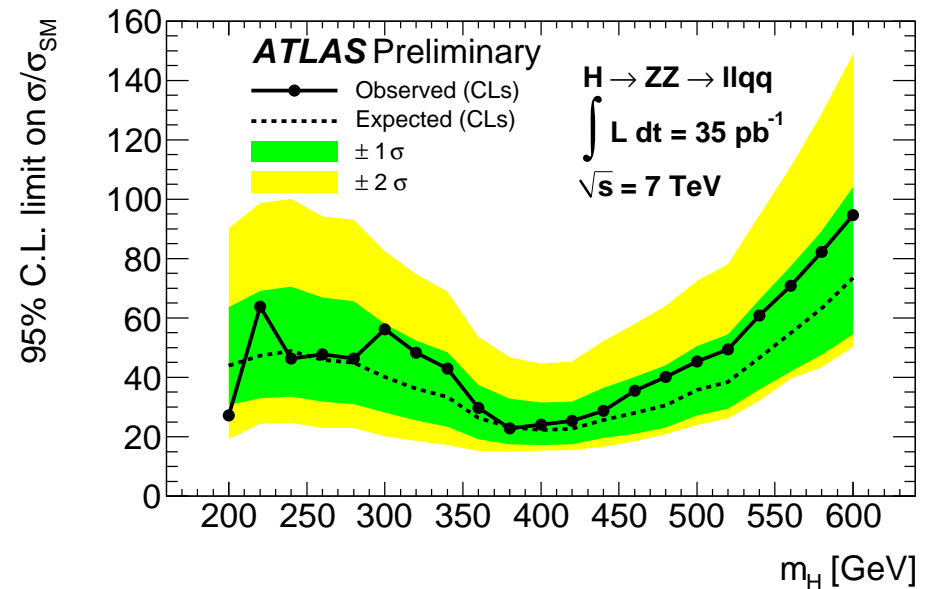
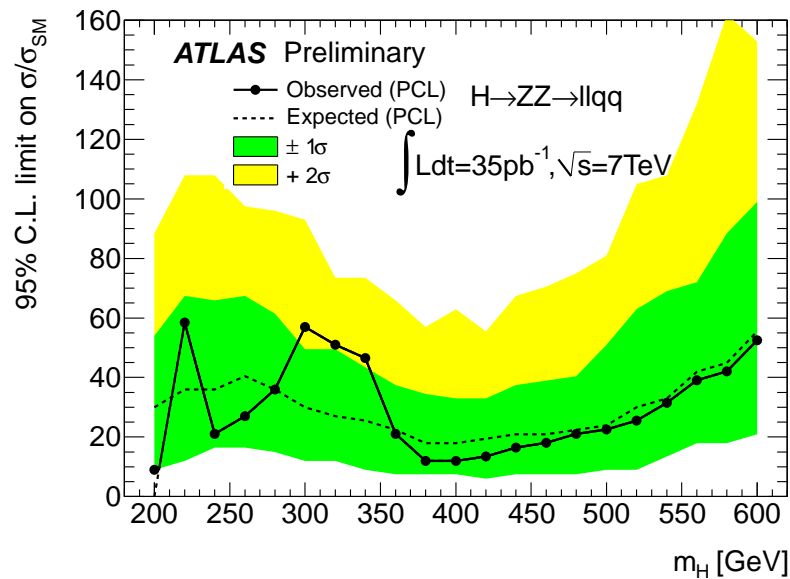
6. The $H \rightarrow ZZ \rightarrow \ell\ell qq$ Search

- Compared to the $H \rightarrow ZZ^{(*)} \rightarrow \ell\ell\ell\ell$ channel, letting one $Z \rightarrow qq$ (or $Z \rightarrow \nu\nu$) increases the branching ratio a lot.
 - The $H \rightarrow ZZ \rightarrow \ell\ell qq$ search is performed for Higgs boson masses in the range $200 < m_H < 600$ GeV.
- Events are selected requiring a pair of leptons and a pair of jets, both consistent with coming from a Z boson decay.



- All decay products from the Higgs boson reconstructed.
 - Look for a signal peak in the $m_{\ell\ell jj}$ distribution.
- For the search at $m_H = 400$ GeV, 0.2 signal events and 10 background events expected.

Exclusion Limit for the $H \rightarrow ZZ \rightarrow \ell\ell qq$ Search

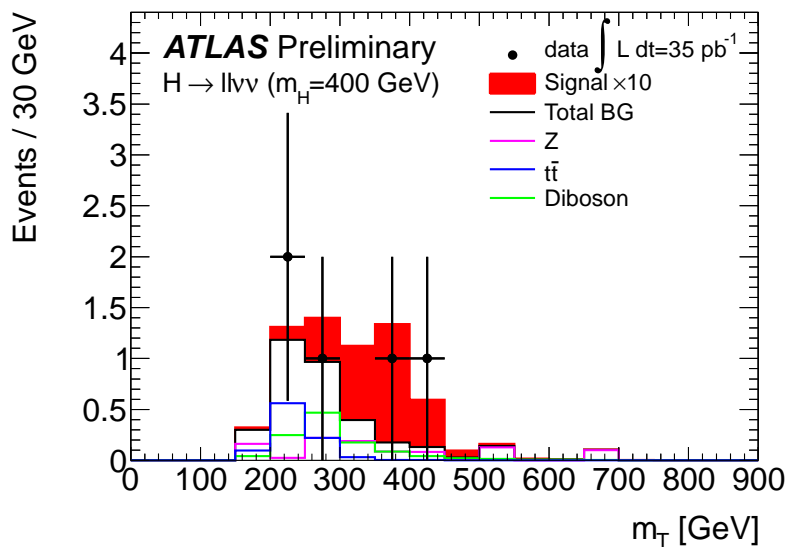


- Exclusion limits obtained in the $H \rightarrow ZZ \rightarrow \ell\ell qq$ search with PCL CL_{s+b} (in the left plot) and CL_s (in the right plot).

7. The $H \rightarrow ZZ \rightarrow \ell\nu\nu$ Search

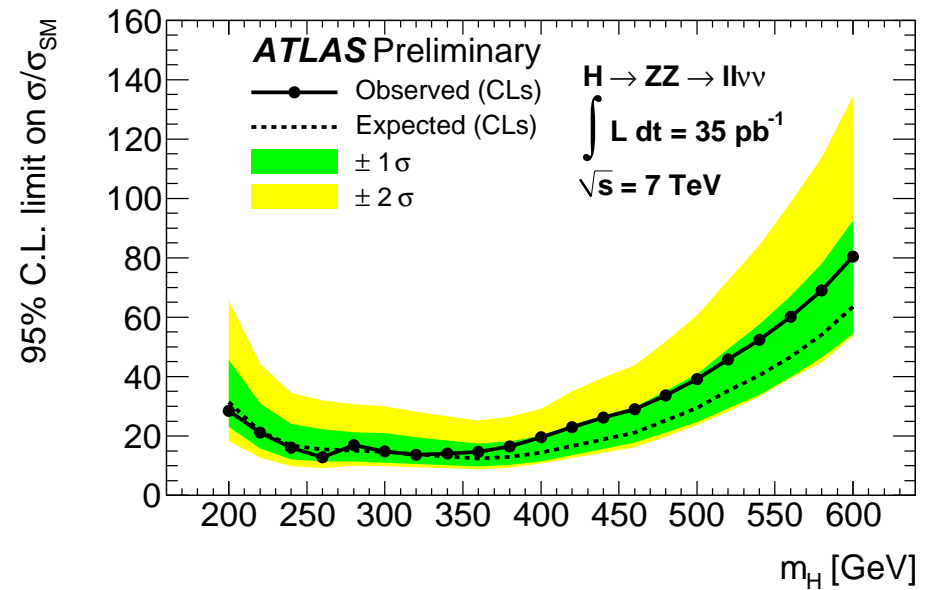
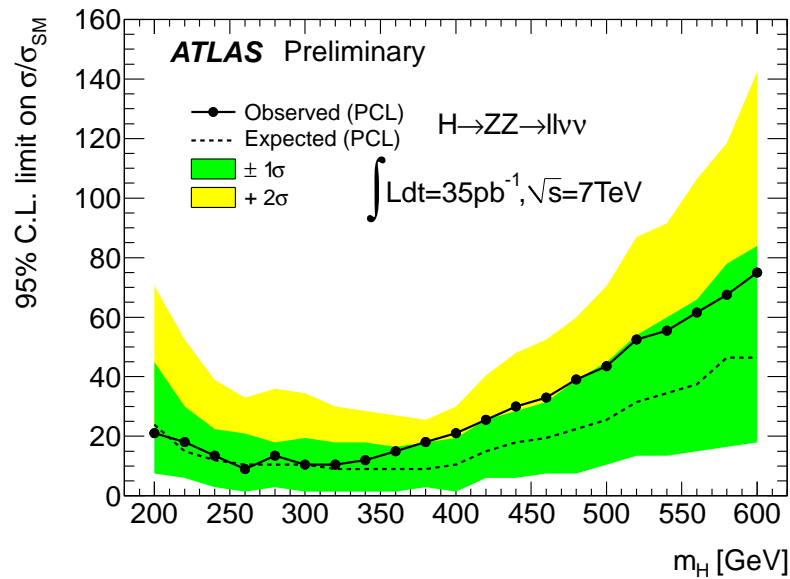
- The $H \rightarrow ZZ \rightarrow \ell\nu\nu$ analysis is very similar to the $H \rightarrow ZZ \rightarrow \ell\ell qq$ search, require high E_T^{miss} instead of the pair of jets.
 - Better background rejection, but no invariant mass peak.
 - Final discriminant is the transverse mass instead, defined as

$$m_T^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\ell\ell}|^2} + \sqrt{m_Z^2 + |\vec{p}_T^{\text{miss}}|^2} \right]^2 - [\vec{p}_T^{\ell\ell} + \vec{p}_T^{\text{miss}}]^2.$$



- Analysis performed for masses in the range $200 < m_H < 600$ GeV.
- For the search at $m_H = 400$ GeV, 0.3 signal events and 3.5 background events expected.
 - Five events are observed passing all selections in data.

Exclusion Limit for the $H \rightarrow ZZ \rightarrow \ell\nu\nu$ Search



- Exclusion limits obtained in the $H \rightarrow ZZ \rightarrow \ell\nu\nu$ search with PCL CL_{s+b} (in the left plot) and CL_s (in the right plot).

8. Conclusions

- Searches for the Higgs boson presented in six different channels.
 - Each search performed in some range of Higgs boson masses.
 - The searches at ATLAS (and CMS) extend to higher Higgs masses than it was possible to cover at the Tevatron.
- Best expected limit is at $m_H = 170$ GeV where a cross section 2.1 times the SM is excluded from the $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ search.
- Some channels have no events observed in data yet, expect an exciting year ahead of us when the \mathcal{L}_{int} increases significantly.

Combined exclusion limit coming soon!